Study on the new materials for fiberboard refiner plate of defibrator

XIANG Hong-liang, LUO Ji-rong, XIAO Ze-hui

Material School of Huazhong University of Science & Technology, Wuhan 430074, P. R. China

Abstract: Defibrator is a very important machine in the wood industry for producing fiberboard. The refiner plates are the key parts of defibrator that directly act with the wood, and broken easily. The working life of the refiner plates is of significance to the wood industry. It may affect refining quality, production efficiency, and power consumption. In this paper, the abrasion resistance of the refiner plate made of different materials, the stainless steels and high chromium cast irons, were tested and compared. The results showed that abrasion resistance of refiner plate made of high chromium cast irons was better than that of the stainless steel materials. Although the two kinds of materials have the same compositions, their abrasion resistances have apparent difference. The main reason is that the material microstructures have very important effects on their performance. The refiner plates made of developed high chromium cast irons don't demand the complex heat treatment. This can simplify the producing process, save the cost of production, decrease labor strength, and increase the production efficiency.

Keywords: Refiner plate; High chromium cast iron; Abrasion resistance; Stainless steel

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Introduction

To produce the fiberboard from wood raw material, the wood chips must be changed into individual fibers or fiber boundless. In thermomechanical pulping, this is accomplished by introducing energy into the wood chip or fiber boundless as the wood chips are passed between a set of counter rotating plates. Thus refiner plates are very important components in refining pulp and are easily broken. The working life span of refiner plates is very important to the production of fiberboard. In general, the refiner plates should have the advantage of abrasion-resistant and better toughness. Ni-hardness cast irons were widely used for the refiner plate material in past years (Thompson *et al.* 1987). Now this kind of material is already obsolete because of their poor toughness and weak abrasion resistances. At present the materials of refiner plate mainly adopted the stainless steels and high chromium cast irons in domestic and oversea (Scholl *et al.* 1997; Tang *et al.* 1997; Stationwala 1987). Although the stainless steels have good abrasion resistances and toughness, producing refiner plates by this kinds of material need heat treatment, which is complex procession and cannot be operated easily, and this makes them very expensive (Ou 1998). High chromium cast irons have better abrasion resistances, but their toughness is weaker than that of stainless steels. And producing the refiner plates by this two materials also need the complex heat treatment. At the same time, considering the self-constructures of refiner plate are complex, and the heat treatment can make them deformation, although the external force can correct it, the fine cracks produced by head treatment or the external force on the root of the refiner plate teeth cannot be found easily. This also can result in incipient fault. Based on this two points, it is necessary to develop new materials which are not only fit for working condition demands of refiner plate including abrasion resistance, good toughness, corrosion resistance but also does not need heat treatment during producing the refiner plate. For this purpose, we develop two kinds of high chromium cast irons, and the refiner plate made of them can take the place of foreign production line.

Material and apparatus

The tested specimens A and B were taken from the used refiner plates. They were also the material of stainless steels. Specimen A comes from the home production, and B from the foreign production line. The specimens C and D were made of high chromium cast irons that were melted in medium frequency induction furnace and cast in sand molds to make into refiner plates. The specimens C and D were not treated by heat. The four components were shown Table 1.

Impact testing specimen size: 10 mm×10 mm×55 mm

Wear testing specimen size: 20 mm×10 mm×3 mm

The experimental apparatus are as follows:

(1)HR150—A Rockwell C hardness machine

(2)JB6 impact test machine

(3)Self made abrasion machine, (Fig.1a, b)

(4)MeF3 optical microscope

(5)150 Kg medium frequency induction furnace

Results

Hardness, impact toughness and microstructures

The mechanical properties for the four materials are

Biography: XIANG Hong-liang (1972-), male, Ph. D. student, Material School of Huazhong University of Science and Technology, Wuhan 430074, P. R. China.

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shown in Table2. Their microstructure see Fig.2-5.

Table1. Compositions of testing materials /%

Specimens	C	Si	Mn	Cr	Ni	Mo	V
A	1.53	1.15	0 9	17.5	1.75	0.89	—
B	1.77	1.03	0.73	24.50	1.02	0.89	
C	2.5~2 8	0.7~1.2	0.4~0.8	22~28	0.6~1.1	0.6~2.0	1.0~4.0
D	2.5~2.8	0.7~1.2	0.4~0.80	22~28	0.6~1.1	0.6~2.0	≤0.4

Abrasion experiment

Every wear specimen was firstly pre-worn on 150# aluminum oxide emery cloth for 30 min. The rotary speed was 340 r/min, the rotary diameter was 120 mm, and load was 2 N. Then they were washed, dried and weighed. After worn for 4 h formally, they were washed, dried and weighed again. The weight loss was measured. Every datum was the mean of three times repeat. The Fig.6 showed their abrasion results.

Table 2. Mechanical properties and microstructures of specimens

Specimens	Impact toughness (J/cm^2)	Hardness (HRC)	Microstructure
A	4.41	53	M+ net carbide
B	4.57	48.5	M+ flack carbide
C	4.23	57.5	M+ dispersion carbide+second carbide
D	3.04	52	A+ M_7C_3

M- martensite; A- austenite; M_7C_3- eutectic carbide;

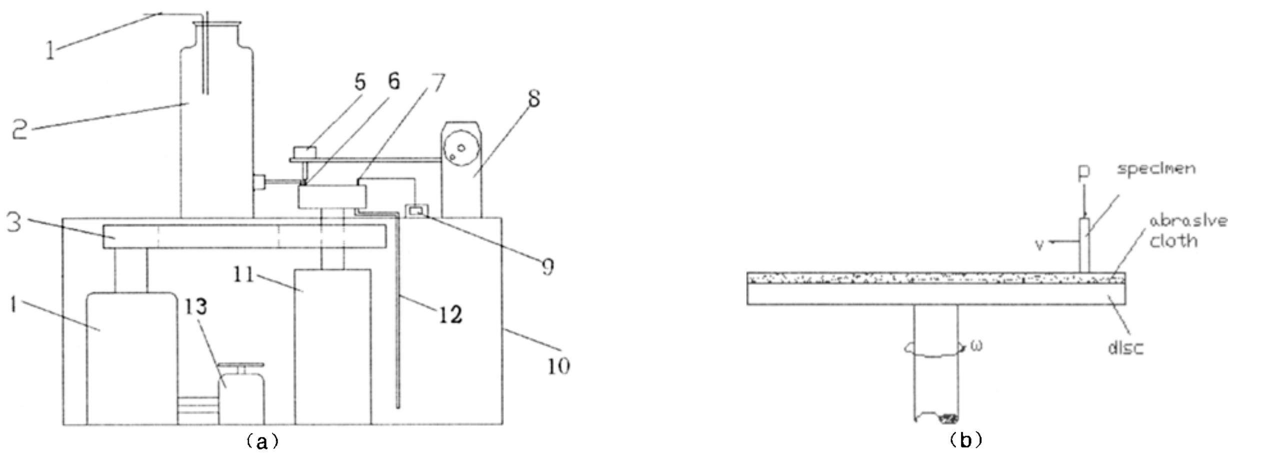

Fig.1 Schematics of wear test machine

1. flow inlet; 2.vessel; 3.belt roller; 4.electric machine; 5.kentledge; 6.test sample; 7.sensor; 8.screw rack; 9.speed counter; 10.carriage; 11.support frame; 12.flow outlet; 13.voltage regulator

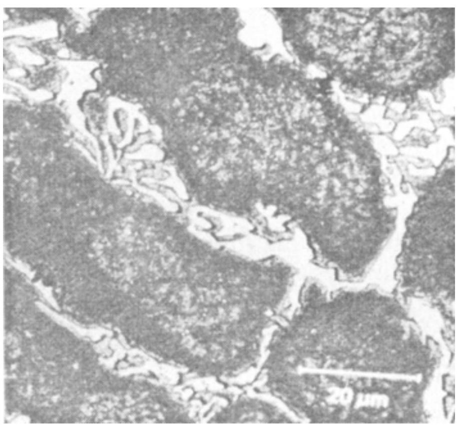

Fig.2 Microstructure of A×500

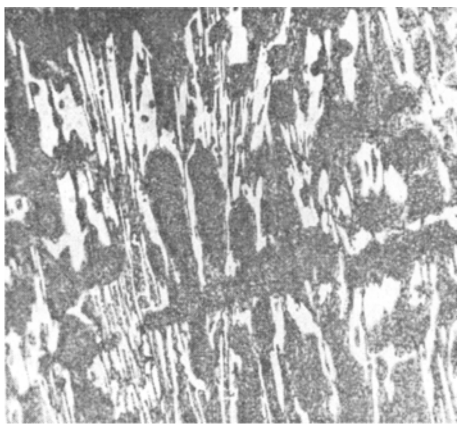

Fig.3 Microstructure of B×500

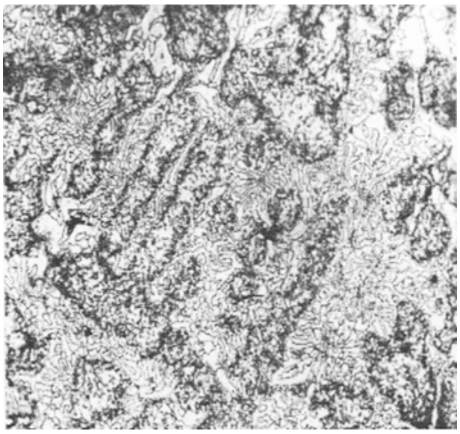

Fig.4 Microstructure of C×500

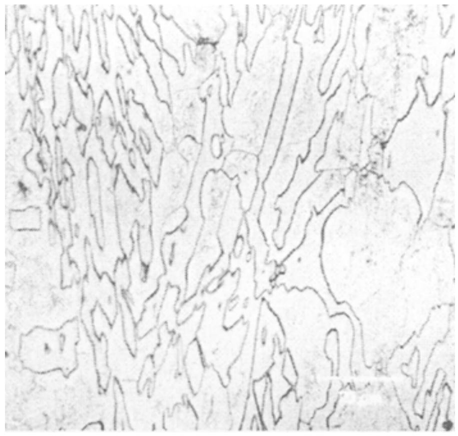

Fig.5 Microstructure of D×500

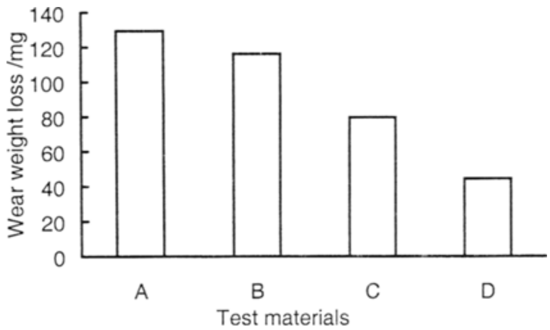

Fig.6 Wear weight loss of four materials

Discussion

Effect of material hardness on the wear of high chromium cast iron and stainless steel

From the tested results, high chromium cast irons have better abrasion resistance than that of the stainless steels, but their toughness is worse. In general thought, the harder material hardness is, the better its abrasion resistance is. Comparing the hardness and abrasion resistance of four materials, the hardness of A is higher than that of B, but its abrasion resistance is worse. The same result can be got from the C and D. So there is not a direct linear relation between the abrasion resistance and hardness. The hardness is only an apparent reference for evaluating the effect of abrasion resistance. Frazier considered that the correlation relation between increasing hardness and increasing service life had limitation (Frazier *et al.* 1981).

Effect of microstructure on the wear of high chromium cast iron and stainless steel

The material microstructure has the very important effects on their performance. For example, though the A and B are the same type steels, their microstructures of carbide are entirely different, and the microstructure of carbide of the A is net, and that of the B is flake. The netlike carbide cuts the matrix seriously and breaks the matrix consistence, which makes the matrix not to get the effectual support. This results in the abrasion resistance and toughness of the A worse than that of the B.

In high chromium cast irons, the matrix of the C specimen is martensite. Its carbide is dispersive and granular, and the structure of the carbide greatly decreases the cutting action on the matrix, and then prevents breaking the matrix integrality and keeps it consistent. The fine carbide phase can change the distribution of applied stresses in the matrix owing to their different resistances to both elastic and plastic deformations. It is advantageous to increase the toughness of high chromium cast iron. The impact-tested results show toughness of the high chromium cast is close to that of the stainless steels. But its abrasion resistance is better than them. The matrix of the D specimen is austenite and its carbide is flake, which is good to abrasion resistance, but it also affects the matrix consistence. Thus its toughness is weak. Although the austenite is softer than martensite, the amount of carbide and its shape can make up for it. If the impact action is not large, abrasion resistance of material D is best. When the impact is great, the material C shows good combination property.

Effect of the main element on the property of high chromium cast iron and stainless steel

The effect of main element in high chromium cast iron can be concluded: (1) Carbon is a main element influencing the hardness, strength, and toughness of material. The more the amount of carbon is, the more the amount of carbide is. But the increase of carbon is not profitable to the corrosion resistance, toughness of materials. And the content of carbon can influences the carbide type. When considering C content, Chromium and Cr/C cannot be ignored. In the high chromium cast iron, Cr is an important element that forms hard chromium eutectic carbide and can strengthen matrix by solid solution effect. When Cr/C is 6~10, carbide can form the ideal M_7C_3 that is very hard. If

the content of Cr is lower, carbide will be M_3C that is not good to abrasion resistance. When the content of Cr is excessive, $M_{26}C_7$ carbide can form easily, which not only decreases abrasion resistances but also consumes alloys. Thus the content of carbon ranges between 2.5% and 2.8%. Cr is between 22% and 28%. (2) Vanadium is a very important element to form carbide. It can make the matrix turn into martensite in cast condition when its content is about 4%. If V is less, it can be instead of Cr in carbide to go into matrix, which can reduce pearlite and increase austenite. (3) Nickel can expand austenite zone, strengthen materials hardenability, and improve its toughness. But it is expensive, and its suitable content is below 1%. (4) Mo has strengthening effect by solid solution, and its suitable content is below 2.0%.

Field test of high chromium cast irons

The refiner plates made of material C and D have been used in fiberboard plates as field tests. The service life span of refiner plate made of D is longer than that of other materials if the impact is lower. If the impact is higher, the material C shows good combination property.

Conclusion

High chromium cast irons have good resistance. They can take the place of stainless steel. There is not a liner relation between hardness and abrasion resistance. It is not right that high hardness is wear resistant. Although the materials have the same compositions, different microstructures result in great difference on abrasion resistance. Using high chromium cast iron to produce refiner plate can simplify the producing process and save the cost of production.

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